Review Panel Summary Report

Modeling Larval Transport and Connectivity in Hawaiian Waters

19-22 May 2008, Honolulu, Hawaii

I. Executive Summary

Computer simulation modeling has been undertaken at the Pacific Islands Fisheries Science Center (NOAA/NMFS) to address insular species issues of metapopulation connectivity and larval transport in the Hawaiian Archipelago. These approaches utilize a variety of remotely-sensed and modeled oceanographic data in a lagrangian modeling framework. These activities have taken place within the Ecosystems and Oceanography Division at the Science Center (Project Leader: Fishery Biologist Donald R. Kobayashi). A review workshop was convened on 19-22 May 2008 at the Hawaii Imin International Conference Center, University of Hawaii East-West Center, Honolulu, Hawaii to provide an independent peer review of these modeling approaches. The review panel was composed of two Center for Independent Experts (CIE) appointed reviewers (Dr. R. K. Cowen, Rosenstiel School of Marine & Atmospheric Science, University of Miami and Dr. K.T. Frank, Bedford Institute of Oceanography, Department of Fisheries and Oceans, Canada). During the review workshop all review material was presented by and discussed with the project leader. The review determined the adequacy, appropriateness, and application of the biological and environmental data used in the analyses, analytical methods and model structure and assumptions applied to the problem of discerning the patterns of archipelagic connectivity among populations inhabiting the Hawaiian Islands. The panel found the research program to be wholly adequate as an approach to the resolution of larval connectivity at the broad geographic scales under consideration. It was recognized the program has been evolving from a generic, coarsely resolved description of larval connectivity to one of finer-scale, species-specific application. The methods and data sources have been appropriate to the objectives and have utilized the best available science. Several recommendations were provided touching upon input and parameterization of the simulation modeling, output and validation of the simulation models, and recommendations of a cross-cutting nature. The consensus of the panel was that the future, potential collective impact of the larval transport and connectivity research program warrants ranking it as a key contributor to the resolution of the high priority major conservation and management issues within the PIFSC.

II. Terms of Reference

1. Evaluate whether the adequacy, appropriateness, and application of data used in the analyses represents the best available science?

The primary type of data used in developing the simulation models can be categorized as either physical or environmental, the majority of which was derived from satellite sensors or output from ocean circulation models. As such, the derived data products are generally widely available to end users and, in most cases, represent the only available source of data at the requisite spatial and temporal scales. These data include the following: a) Topex Poseidon altimeter and its various successors including ERS, JASON, AVISO which provided the geostrophic flow fields and the bathymetry product used in the simulations; b) OSCAR – Ocean Surface Current Analysis Real time which provided combined geostrophic and wind driven flow fields; c) SST and surface chlorophyll derived from AVHRR and SeaWiFs; d) Positional information on satellite drifter buoy tracks used for the flow field validation; e) TAO oceanographic mooring data used to compare observed mixed layer depth to the prediction from Topex altimetry; f) model outputs from NLOM – Naval Research Laboratory Layered Ocean Model; g) model outputs from NCOM – Naval Research Laboratory Coastal Ocean Model; h) University of Hawaii tidal model output; and i) various climate indices such as the SOI – Southern Oscillation Index and PDO – Pacific Decadal Oscillation Index. In each case examined, it was concluded that the data were adequate and appropriate for the simulation modeling exercise. It should be noted that the resolution of the flow field data used became increasingly higher and served to improve the simulation results, a trend expected to continue in the future. However, due to the limited time series for the higher resolution flow field data, some applications will be better served with the lower resolution, longer time series data.

2. Evaluate whether the adequacy, appropriateness, and application of analytical methods and modeling represents the best available science?

A variety of analytical and statistical methods were employed to search for patterns in the simulated particle distributions, partition variance in settlement output data, validate particle trajectories, and summarize dispersal outcomes. The analytical methods included: a) Generalized additive modeling (GAMs); b) NMDS (non-metric multi-dimensional scaling); c) Linear regression analysis; d) Student's t-test; e) a contouring algorithm for spatial analysis known as ConREC; and f) Matrix presentation of the probability density functions. All the analytical/statistical methods were adequate and appropriately applied and have precedent in the contemporary ecological literature dealing with connectivity research.

3. Do the biological data, population data, model structure and assumptions, and the analysis methods applied to archipelagic connectivity represent the best available data and methodology for sound science?

The Lagrangian simulation model is based upon an individual based modeling structure, incorporating a random walk subcomponent. The approach is the appropriate framework for addressing larval dispersal and general questions of connectivity across large geographic scales. The development and application of this model rests upon several assumptions including: a) a constant diffusivity of 500 m^2/s; b) spawning output proportional to habitat area defined by the 0-100m depth range; c) a constant rate of spawning throughout the year (uniform distribution); d) pelagic larval duration or PLD ranging from 15 – 365 days, with no variability in settlement at the imposed PLD; e) a circular settlement zone of detection by dispersing larvae with a radius of 25 – 140 km; f) a passive and mixed (occupation of different broad layers) vertical distribution of larvae depending on the simulation run; and g) no response by dispersing larvae to coastal boundaries. The primary data input to the simulation model was the u and v components from altimetry or NLOM and these were taken to be representative of the flow fields dispersing larvae experienced. The assumptions were considered reasonable and appropriate given the scale of resolution evaluated, particularly when the simulations were based on flow field input from the altimeter. However, several of the assumptions will require modification in order to move the modeling from its present generic emphasis to a species-specific, high resolution depiction of the dispersal/connectivity process.

Output from the Lagrangian simulations were used in a multiple generation metapopulation model. An important component of this model was the imposition of density dependence on spawning output (capped at an input value based on the number of simulation runs scaled by available habitat). A constraint to this exercise was that the derived measures of connectivity were based on a single year of modeled flow fields but applied to 1000 generations. This modeling exercise was illustrative of the potential development of spatial structure and biogeographic patterning among populations in the Hawaiian archipelago. This was considered a minor and largely exploratory component of the larval connectivity research program. The extremely long times scales associated with this exercise makes it less relevant to potential management applications, although the generation length was not specified.

The simulation modeling exercise was intended to be strictly generic and as such no species specific biological or population level data was used. Only the PLD parameter was based upon a broad range of known values. It appeared that moving forward with the simulation modeling required making several assumptions (e.g. constant spawning timing, location and egg production), rather than waiting for detailed information to eventually become available. Embarking on such a strategy was deemed appropriate. Several suggestions were offered as recommendations to lessen the dependence on the existing assumptions.

III. Further Analyses and Evaluations

During the course of the on-site review several requests were made concerning the availability of information related to the general level of interest in larval connectivity research and its application to the Hawaiian archipelago. A request was also made for details of the spiny lobster CPUE time series at other locations besides Maro reef and Necker Island. A last request was made for further information on the area closures and the associated restrictions within these areas for the Main Hawaiian Islands. All of the requested material was provided and discussed. At no time during the review were further analyses or evaluations requested.

IV. Additional Comments

Additional discussions were centered on a variety of topics many of which represented obvious future directions leading to improvements in the larval transport and connectivity research program. The additional topics discussed ranged from exploring newer circulation model data, incorporating larval behavior such as orientation and horizontal swimming, re-coding the model into a more efficient language, and development of a connectivity web interface for resource managers resembling the connectivity web interface developed by CSIRO. One near future development was discussed involving the merger of two flow field models involving the collaboration with University of Hawaii scientists. This initiative was described as a possible regional contribution to the CAMEO program.

V. Recommendations

The panel made recommendations that are grouped into three categories associated with i) input/parameterization of the simulation modeling, ii) output/validation of the simulation models, and iii) recommendations of a cross-cutting nature.

i) <u>Input/parameterization for simulation models</u>

Basic biological data, based on literature review and directed research, to develop connectivity models for target species is needed. Data on the space/time distribution of spawning for selected species and, if possible, some measure of inter-annual variability (comprehensive description of where, when, how long and how much spawning occurs) should be compiled. Similarly, consideration should be given to including estimates of egg and larval mortality, developmental rates, vertical and horizontal behavior, all in the context of the ambient environmental conditions.

Further evaluation and possibly modification of the choice of the single eddy diffusivity constant used for the wide variety of simulations undertaken is required. This will be particularly important with respect to the effect of changing grid scales. Further, empirical evaluation of the eddy diffusivity constant should be considered such as through buoy deployment, dye or particle releases.

There is a need for multiple year data products from the ocean modeling to extend the simulations to other years and build links to the physical oceanographic community to ensure timely delivery and interpretation of flow field data.

Since it is unlikely that the geostrophic flow fields and the regional ocean circulation models adequately resolve shallow coastal water flow fields where the spawning production is assumed to occur, there is a need to couple higher resolution models.

A sensitivity analysis should be conducted to evaluate the influence of the assumptions associated with the imposed coastal boundary conditions.

Maintaining flexibility in the Lagrangian particle tracking component of the simulation model to accommodate a variety of new or future flow field inputs is viewed as an important consideration.

ii) <u>Output/validation of simulation models</u>

Validation of the simulation results is presently hampered by the non-specific profile of the model organism. There is an obvious need to develop species-specific scenarios for validation purposes.

The data derived from historical ichthyoplankton surveys around the Hawaiian archipelago may provide one way of evaluating the model output and should be explored.

Initiation and maintenance of fishery-independent surveys to assess larval and/or juvenile abundances, for assessment of the correspondence between simulation results and empirical observations, is required. In addition, testing could be achieved through model-directed sampling of predicted densities or distributions.

Model validation can also be achieved through studies that characterize population structures, including direct and indirect tagging studies (e.g. genetic markers, otolith micro-chemistry, isotopes, conventional tags).

Efforts to validate outputs of the physical models should be restricted to those aspects dealing with the choice of diffusivity constants. Aspects beyond this sort of validation should be deferred to the originators of the ocean circulation models.

iii) <u>Cross-cutting</u>

It is anticipated that in the near future the larval connectivity research program will reach a stage of development where a wide variety of potential applications will exist, including a redefinition of the spatial scale of fishery management units, a first-order description of the metapopulation structure for economically and ecologically key species, and in the evaluation and future citing of marine protected areas. The future, potential collective impact of this research program warrants ranking it as a key contributor to the resolution of the high priority major conservation and management issues within the PIFSC.

The anticipated, positive developments within the larval connectivity research program will require a commitment to the timely production of reports and publications to be vetted within the local as well as broader scientific community.

Effort should be expended to develop a web interface to provide information on the connectivity data products for the Hawaiian Island archipelago. A potential framework for such a development is the CSIRO connectivity interface.

It is anticipated that improvements to the modeling as recommended will strain existing resources, in terms of personnel and computing hardware. Steps should be taken to ensure that this is not a limitation to the execution of future applications.

VI. Chairs Statement

The contents of the Summary Peer Review Report provide an accurate and concise summary of the panel review discussions and independent reviewer's views on the issues covered. All panel members were extremely impressed with the clarity and content of the presentations, the broad, multi-faceted scope of the research program, and the scientific capability of the lead investigator, Donald Kobayashi. The panel was curious about the lack of participation by additional NOAA Ecosystem and Oceanography Division scientific staff in the 19-22 May 2008 review at the Imin East-West Conference Center, leaving Mr. Kobayashi alone to shoulder the weight of the review. While we recognize it is possible that prior commitments did not make it possible for attendance by some staff, our concern remains.

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